I, Takashi Kawamukai, being familiar with the Japanese and English languages, hereby declare that I am the translator of the documents attached and certify that to the best of my knowledge and believe the following is a true and accurate translation of Japanese Patent Application No. 2002-285141.

Signed T. Kawamukai

Takashi Kawamukai

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[Item] Specification 1

[Item] Drawings 1

[Item] Abstract 1

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[Title of the Document] Specification

[Title of the Invention] PRODUCTION METHOD FOR POWDERED CORE

[Claims]

[Claim 1]

A production method for a powdered core, comprising:

preparing a mixture including a soft magnetic powder and a resin powder;

compacting the mixture into a predetermined shape to obtain a green compact; and

heating the green compact;

wherein the resin powder has a median size of not more than 50 μm, and the resin powder amount is 0.01 to 5 vol%.

[Claim 2]

A production method for a powdered core according to claim 1, wherein the resin powder is made of a thermoplastic resin.

[Claim 3]

A production method for a powdered core according to claim 1, wherein the resin powder is a thermosetting resin with a median size of 30 μm or less.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a production method for a powdered core, which is used for electric transformers, reactors, thyristor valves, noise filters, choke coils, and the like. In particular, the present invention relates to a

resistivity ρ by limiting the eddy-current in a small area. In a powdered core obtained by using powders, for example, nonmagnetic resin can exist between iron powder particles, and the like. Therefore, the powdered core has essential characteristics in which the resistivity ρ is high and the eddy-current loss W_e is small. Conventionally, a production technique for a powdered core was proposed in Patent Document 1 in which a mixture of a soft magnetic powder and a resin powder was used, and compacting and heating were performed. In the powdered core, resin existed between soft magnetic powder particles. Therefore, electrical insulation between the soft magnetic powder particles was specifically assured, whereby the eddy-current loss W_e was decreased, and the soft magnetic powders were tightly bound, whereby strength of the powdered core was increased.

[0005]

[Patent Document 1]

Japanese Laid-open Patent Application No. S60-235412 (pages 1 and 2)

[0006]

The powdered core mentioned above has been widely used because it is easy to produce. However, when the powdered core is used in a high frequency area, the insulation characteristics are not sufficient, whereby the resistivity ρ is decreased, resulting in increasing the eddy-current loss W_e. The increase in eddy-current loss W_e causes heat generation, whereby resin binding the soft magnetic powder is deteriorated. Therefore, the powdered core has a disadvantage in that sufficient durability cannot be obtained. On the other hand, when the resin amount is increased in order to increase the electrical insulation,

the amount of the soft magnetic powder contained in the core (packing factor) is decreased, whereby the magnetic flux density is decreased. Therefore, it is important to increase the magnetic flux density by increasing the density of the powdered core. However, in this case, the powder must be compressed at a high pressure, and strain is generated in the soft magnetic powder in compacting. Therefore, the hysteresis loss W_h would increase and the iron loss W would increase. Specifically in a low frequency area, the eddy-current loss W_e is small, whereby effect of the hysteresis loss W_h for the iron loss W is large. Decrease in the hysteresis loss W_h is also important in order to decrease the iron loss W.

[0007]

[Subjects Solved by the Invention]

According to these findings, in order to simultaneously decrease the eddy-current loss W_e and the hysteresis loss W_h, various methods for decreasing the eddy-current loss W_e by assuring electrical insulation between the soft magnetic powder particles by preliminarily coating insulation film over the surface of the soft magnetic powders are disclosed, for example, in Patent Document 2. In a technique described in the above laid-open disclosure, a process in which the insulation film is coated on the surface of the soft magnetic powder is essential, thereby having a disadvantage of having high production cost. Recently, it has been requested to develop the production method for a powdered core in which low production cost can be realized, the eddy-current loss W_e and the hysteresis loss W_h are decreased, and durability of the powdered core can be improved.

[0008]

[Patent Document 2]

Japanese Laid-open Patent No. H9-102409 (pages 6 and 7)

[0009]

The present invention has been made to essentially realize low production cost without performing special processes including coating of insulation film. A object of the present invention is to provide a production method for a powdered core, in which electrical insulation is increased by uniformly disposing a resin between soft magnetic powder particles, whereby the eddy-current loss W_e in a high frequency area and heat generation caused by the W_e are decreased, thereby improving the durability of the powdered core. Another object of the present invention is to provide a production method for a powdered core, in which magnetic flux density is sufficiently assured by thinly disposing the resin between the soft magnetic powder particles, whereby the hysteresis loss W_h and heat generation caused by the W_h are decreased, thereby further improving the durability of the powdered core. In the case of coating the insulation film over the surface of the soft magnetic powder in the present invention, there is an additional object that the electrical insulation is assured at higher levels and the magnetic flux density is further increased by decreasing the resin amount used, whereby the durability of the powdered core is further improved.

[0010]

[Means for Solving the Subjects]

The inventors have intensively researched so as to solve the

above-mentioned problems. As a result, the inventors have found that electrical insulation sufficient to assure an adequate durability of a powdered core cannot be obtained in the conventional powdered core, since the resin is nonuniformly disposed in the obtained powdered core, that is, the resin is not uniformly disposed between the soft magnetic powder particles. The inventors have researched regarding the above-mentioned phenomenon by specifically giving attention to the particle size of the resin powder to assure the electrical insulation, and have found the following findings. That is, when resin powder having a conventional median size (particle diameter at 50% of cumulative distribution) of about 100 μm is used, the resin powders have been nonuniformly disposed in the powdered core under a compacted condition, whereby even if thermoplastic resin powder is used, the resin powder is not sufficiently infiltrated between the soft magnetic powder particles, resulting in the resin powder remaining in a nonuniform condition. Therefore, the inventors have found that if the resin powders are uniformly dispersed in the soft magnetic powder particles in compacting, the resin is uniformly disposed between the soft magnetic powder particles after a heat treatment, whereby the electrical insulation is assured. The inventors have further researched according to the above-mentioned findings. As a result, the inventors found that when a resin powder having small median size is used, the resin powders can be easily disposed between the soft magnetic powder particles, whereby a powdered core in which the resin is uniformly disposed between the soft magnetic powder particles after the heat treatment can be obtained.

[0011]

A production method for a powdered core of the present invention includes steps of preparing a mixture including a soft magnetic powder and a resin powder, compacting the mixture into a predetermined shape to obtain a green compact, and heating the green compact, wherein the resin powder has a median size of not more than 50 μm, and the resin powder amount is 0.01 to 5 vol%.

[0012]

In the present invention, a special treatment to coat an insulation film over the surface of the soft magnetic powder is not necessary, unlike in the case of a powdered core described in Patent Document 2, whereby low production cost can be realized. In the present invention, as mentioned above, a resin powder having a median size of not more than 50 μm is used, whereby electrical insulation is increased by uniformly disposing the resin between the soft magnetic powder particles, and the eddy-current loss W_e in a high frequency area and heat generation caused by the W_e are decreased, thereby improving the durability of the powdered core and improving the performance of products using the powdered core. In the present invention, the resin powder amount is 0.01 to 5 vol%. By setting the resin powder amount to be not less than 0.01 vol%, sufficient electrical insulation is assured, whereby the eddy-current loss W_e in high frequency area and heat generation caused by the W_e are decreased, thereby further improving the durability of the powdered core. On the other hand, by setting the resin powder amount to be not more than 5 vol%, magnetic flux density is sufficiently assured by thinly disposing the resin between the soft magnetic powder particles, whereby the hysteresis loss W_h and heat generation

caused by the W_h are decreased, thereby further improving the durability of the powdered core. In the production method for a powdered core of the present invention, low production cost is realized without performing special treatments on the soft magnetic powder, and improvement of the durability of the powdered core is realized by improvement of the median size and amount of the resin powder used.

[0013]

In the present invention, conventional resins which are added to a powdered core can be used. Polyimide resin and the like can be used in the case of application in which heat resistance is required, and inexpensive epoxy resin and the like can be used in the case of applications other than the above-mentioned application.

[0014]

An insulation coating treatment is not required for a soft magnetic powder used in the production method of the present invention, and conventional soft magnetic powders can be sufficiently used. In the case of coating an insulation film over the surface of the soft magnetic powder, the electrical insulation is assured at a higher level and the magnetic flux density is further increased by decreasing the resin amount used, whereby a powdered core in which the durability is further improved can be provided. In the case of using a soft magnetic powder having a median size which is too small, the specific surface area of the soft magnetic powder is increased, thereby decreasing the electrical insulation. Therefore, a soft magnetic powder having a median size of not less than 50 μm is preferably used.

the resin D was a conventional type which was not suitable for a production method of the present invention. Each resin A to D was added at 1.75 vol% to electrically insulated iron powder coated with phosphate, and the resin and the iron powder were mixed, whereby a mixture was respectively produced. These mixtures were compacted at a compacting pressure of 980 MPa to obtain green compacts having a ring shape in which the inner diameter was 20 mm, the outer diameter was 30 mm, and the height was 5 mm, and these green compacts were heated and held at 200°C for 5 hours, whereby powdered cores were produced.

[0018]

By using each powdered core having the ring shape as produced above, eddy-current loss W_e and hysteresis loss W_h were respectively measured in a range at a exciting magnetic flux density of 0.05 to 1 T and a frequency of 50 to 2000 Hz. The results are shown in Table 1, Fig. 2 and Fig. 3. A result of iron loss W obtained by adding the W_e to W_h is shown in Table 1 and Fig. 4. SEM images and EPMA images concerning the powdered core obtained by using the resin A (Invention Example) and the powdered core obtained by using the resin D (Conventional Example) were taken, whereby distribution condition of carbon (resin) was examined in the shot field. Fig. 5A is a SEM image of an Invention Example, Fig. 5B is an EPMA image of an Invention Example, Fig. 5C is a SEM image of a Conventional Example, and Fig. 5D is an EPMA image of a Conventional Example. In the SEM images, particle boundary and resin are shown in black portions, and in the EPMA images, carbon included in the resin is shown in white portions.

[0019]

[Table 1]

measured characteristic	resin type	frequency (Hz)							
		50	60	100	200	500	1000	1500	2000
eddy-current loss We (W/kg)	resin A	0.01	0.02	0.04	0.17	1.10	4.43	9.66	17.16
	resin B	0.08	0.11	0.30	1.21	7.82	28.31	49.00	82.00
	resin C	0.09	0.13	0.35	1.41	7.98	34.50	78.00	134.00
	resin D	0.19	0.26	0.74	2.98	18.81	75.40	169.77	291.19
hysteresis loss Wh (W/kg)	resin A	7.13	8.41	14.10	27.88	72.00	141.80	211.30	275.00
	resin B	6.91	8.30	13.84	27.49	71.15	141.27	210.13	274.46
	resin C	7.21	8.35	14.20	27.80	72.30	142.10	213.00	278.00
	resin D	7.28	8.48	14.66	29.33	74.17	148.63	223.11	287.00
Iron loss W (W/kg)	resin A	7.14	8.43	14.14	28.05	73.10	146.23	220.96	292.16
	resin B	6.98	8.41	14.14	28.69	78.97	169.58	259.13	356.46
	resin C	7.30	8.48	14.55	29.21	80.28	176.60	291.00	412.00
	resin D	7.47	8.74	15.41	32.30	92.99	224.03	392.87	578.19

[0020]

As shown in the Table 1 and Figs. 2 to 4, when the median size of the resin particles is smaller, the decreasing effect of the eddy-current loss W_e is larger even in the high frequency area, whereby iron loss W is further decreased. As shown in distribution condition of the carbon (resin) in the Figs. 5A to 5D, in the Conventional Example having large median size, the carbon is nonunifiormly disposed in pores of the powdered core (see Figs. 5C and 5D). On the other hand, in the Invention Example having small median size, the

carbon is distributed not only in the pores but also along the particle boundary of the powder (see Figs. 5A and 5B). In the Invention Example, the electrical insulation between the iron powder particles is sufficiently assured, whereby the eddy-current loss W_e is decreased even in the high frequency area, resulting in decreasing the iron loss W. As mentioned above, it is demonstrated that, by using a resin having a median size of not more than 50 μm, the electrical insulation can be increased by sufficiently disposing the resin between iron powder particles, whereby the eddy-current loss W_e is sufficiently decreased even in the high frequency area, resulting in sufficiently decreasing the iron loss W.

[0021]

[Practical Example 2]

4 kinds of resins A to D were added in various amounts to an electrically insulated iron powder coated with phosphate, and 4 kinds of resins A to D were added in various amounts to a pure iron powder in which an insulation treatment is not performed. After the addition, the resins and iron powders were mixed to respectively produce the mixtures. By using these mixtures, a green compact having a ring shape in which the inner diameter was 20 mm, the outer diameter was 30 mm, and the height was 5 mm, and a green compact having a plate shape in which vertical size was 12.7 mm, horizontal size was 31.75 mm and thickness was 5 mm were obtained at a compacting pressure of 980 MPa. These green compacts were heated and held at 200°C for 5 hours, whereby powdered cores were produced.

[0022]

In the powdered cores having the ring shape among the powdered cores as produced above, the resistivity was measured by a 4 point probe method, and the magnetic flux density was measured in a range of a magnetizing force of 10000 A/m. In the powdered cores having the plate shape in the powdered cores as produced above, a bend strength was measured by a three point bending test. The result of the resistivity is shown in Table 2, the result of the magnetic flux density is shown in Table 3, and the result of the bend strength is shown in Table 4.

[0023]

[Table 2]

measured characteristic	resin type	resin amount (vol%)							
		0.00	0.01	0.85	1.75	2.65	3.50	5.00	5.75
resistivity (μΩcm)	resin A + electrically insulated iron powder	2,000	7,800	412,657	554,725	2,466,778	8,283,248	14,230,025	17,658,882
	resin B + electrically insulated iron powder	2,000	3,100	74,700	159,300	239,900	557,800	761,000	973,400
	resin D + electrically insulated iron powder	2,000	2,200	3,000	5,000	7,100	8,800	9,800	11,000
	resin A + pure iron powder	300	455	13,500	27,000	35,000	41,300	50,000	57,700

[0024]

[Table 3]

Measured characteristic	resin type	resin amount (vol%)							
		0.00	0.01	0.85	1.75	2.65	3.50	5.00	5.75
magnetic flux density $B_{10000A/m}$ (T)	resin A + electrically insulated iron powder	1.76	1.76	1.69	1.64	1.60	1.56	1.50	1.44

[0025]

[Table 4]

measured characteristic	resin type	resin amount (vol%)							
		0.00	0.01	0.85	1.75	2.65	3.50	5.00	5.75
bend strength (MPa)	resin A + electrically insulated iron powder	53.85	57.30	67.20	94.72	107.31	117.04	117.30	117.53
	resin B + electrically insulated iron powder	54.56	56.10	61.80	62.53	71.74	83.00	95.60	105.11
	resin D + electrically insulated iron powder	52.78	54.00	60.50	62.74	66.60	74.16	76.30	79.08

[0026]

As shown in Table 2, in each powdered core, when the resin amount is 0.01 vol%, an increase in the resistivity was observed in comparison with a case of adding no resin. In each powdered core, when the resin amount is larger, the resistivity is higher. In the powdered core obtained by using a resin D (Conventional Example) having a large median size, even if the resin is added at 5.75 vol%, the resistivity is 11000 μΩcm which is extremely low. Accordingly, when the resin having a small median size is used, an effect equal to the case of using the resin having a large median size can be obtained with an extremely small amount of resin. Even if the ordinary pure iron powder is used without using an iron powder coated with an expensive phosphate, a higher resistivity compared with a resistivity in the case of mixing the iron powder conducting the insulation coating treatment and the conventional resin (a rein having large median size) is obtained by adding a small amount of the resin having the small median size.

[0027]

As shown in Table 4, when the resin amount is increased, bend strength is increased in each powdered core. The increasing effect appears more extremely when the median size of the resin is smaller. As shown in the Table 3, when the resin amount is larger, the magnetic flux density is lower. When the resin amount exceeds at 5 vol%, the magnetic flux density is less than 1.5 T. When the powdered core is used as an electric component and core for various motors, a characteristic of not less than 1.5 T is required, whereby an addition of the resin at not less than 5 vol% is not preferable. As mentioned above, when the resin amount is not less than 0.01 vol%, an increase in the resistivity is

observed. When the resin amount is more than 5 vol%, the magnetic flux density is decreased. Accordingly, the resin amount is preferably 0.01 to 5 vol%.

[0028]

[Effects of the Invention]

In the powdered cores obtained by production methods of the present invention, the special treatment, for example, insulation coating treatment by resin, is not necessary, whereby a low production cost can be realized. Since electrical insulation is increased by uniformly disposing the resin between soft magnetic powder particles, the eddy-current loss W_e in a high frequency area and heat generation caused by the W_e are decreased, thereby improving the durability of the powdered core. Since magnetic flux density is sufficiently assured by thinly disposing the resin between the soft magnetic powder particles, the hysteresis loss W_h and heat generation caused by the W_h are decreased, thereby further improving the durability of the powdered core. In the case of coating an insulation film over the surface of the soft magnetic powder, the electrical insulation is ensured to be at a higher level and the magnetic flux density is further increased by decreasing the resin amount used, whereby a powdered core in which the durability is further improved. Therefore, the present invention is anticipated to be able to produce powdered cores suitable for various magnetic components.

[Brief Description of the Drawings]

[Fig. 1] A graph showing relationships between amount of particles and particle diameter for 4 kinds of resins A to D.

[Fig. 2] A graph showing relationships between eddy-current loss W_e and frequency f concerning powdered cores produced by adding the 4 kinds of resins A to D described in the Fig. 1 to electrically insulated iron powder.

[Fig. 3] A graph showing relationships between hysteresis loss W_h and frequency f concerning powdered cores produced by adding the 4 kinds of resins A to D described in the Fig. 1 to electrically insulated iron powder.

[Fig. 4] A graph showing relationships between iron loss W and frequency f concerning powdered cores produced by adding the 4 kinds of resins A to D described in the Fig. 1 to electrically insulated iron powder.

[Fig. 5] Fig. 5A is a SEM image of a practical example, Fig. 5B is an EPMA image of a practical example, Fig. 5C is a SEM image of a conventional example, and Fig. 5D is an EPMA image of a conventional example.

[Title of the Document] Abstract

[Subject] An object is to provide a production method for a powdered core in which low production cost can be realized, the eddy-current loss W_e and the hysteresis loss W_h are decreased, and durability of the powdered core can be improved.

[Means for Solving the Subjects] A production method for a powdered core includes: preparing a mixture including a soft magnetic powder and a resin powder; compacting the mixture into a predetermined shape to obtain a green compact; and heating the green compact. The resin powder has a median size of not more than 50 μm, and the resin powder amount is 0.01 to 5 vol%.

[Selected Drawing] None

Fig. 1

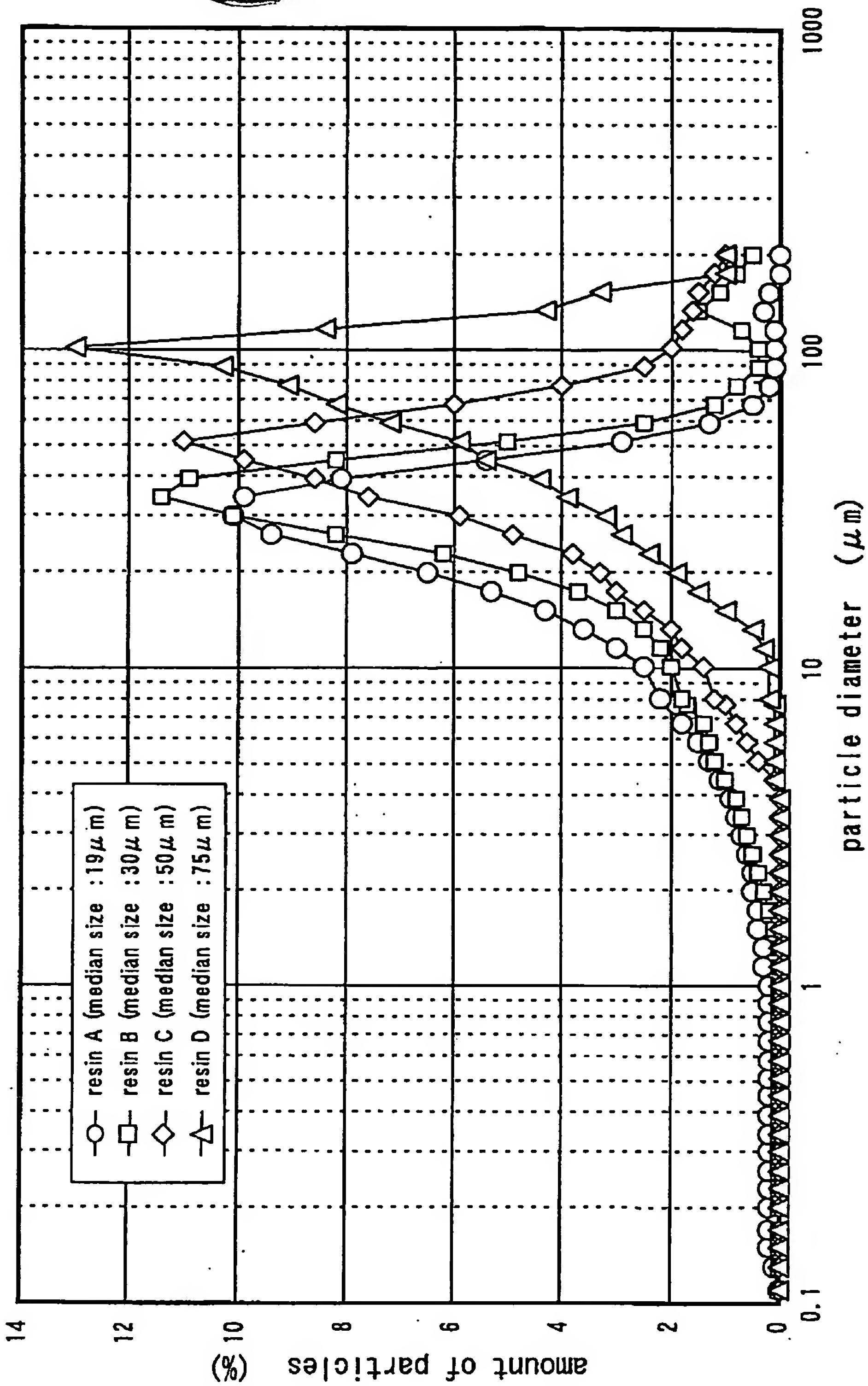

resin A (median size :19μm)
resin B (median size :30μm)
resin C (median size :50μm)
resin D (median size :75μm)
particle diameter (μm)
amount of particles (%)
0.1
1
10
100
1000
0
2
4
6
8
10
12
14

Fig. 3

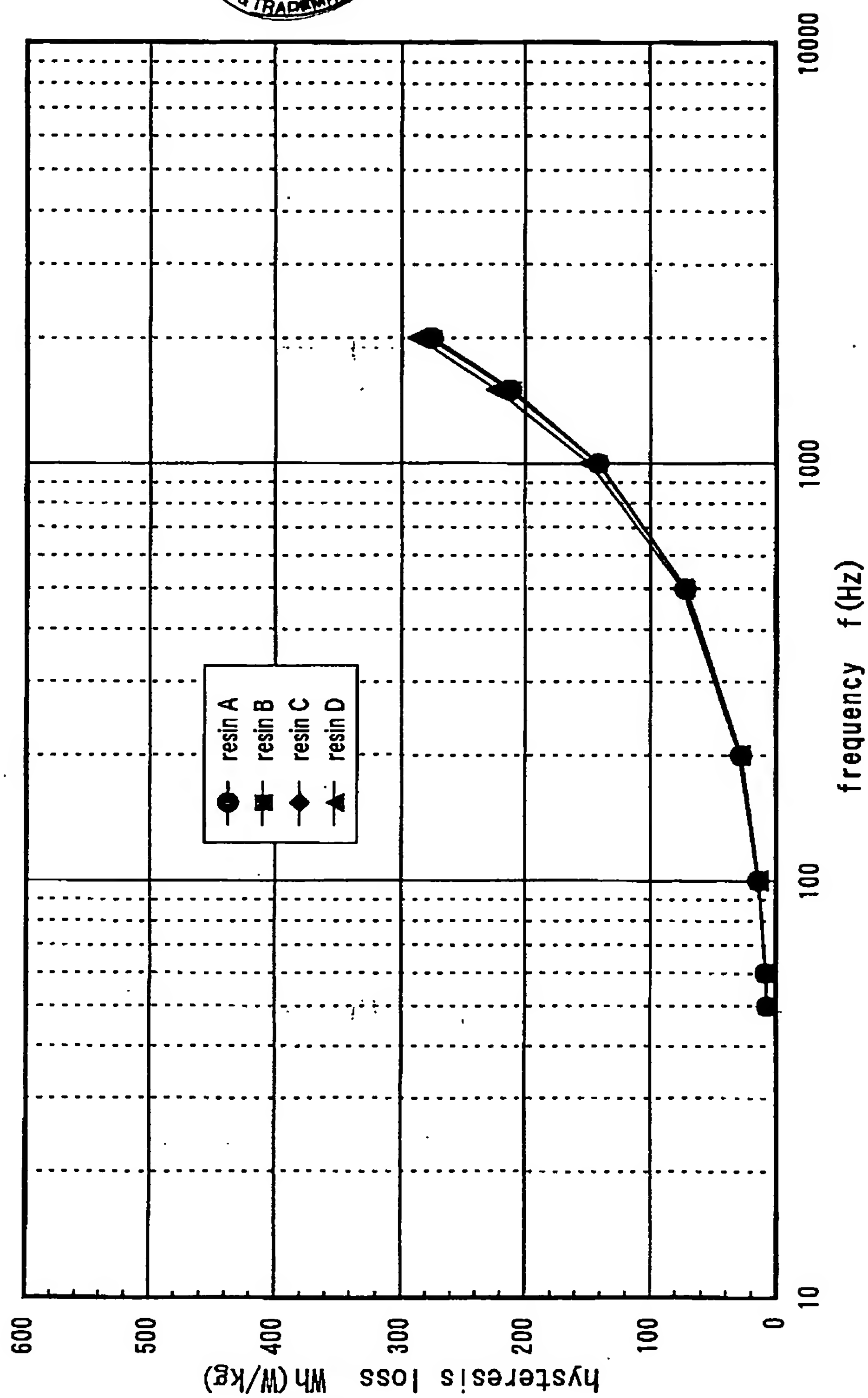
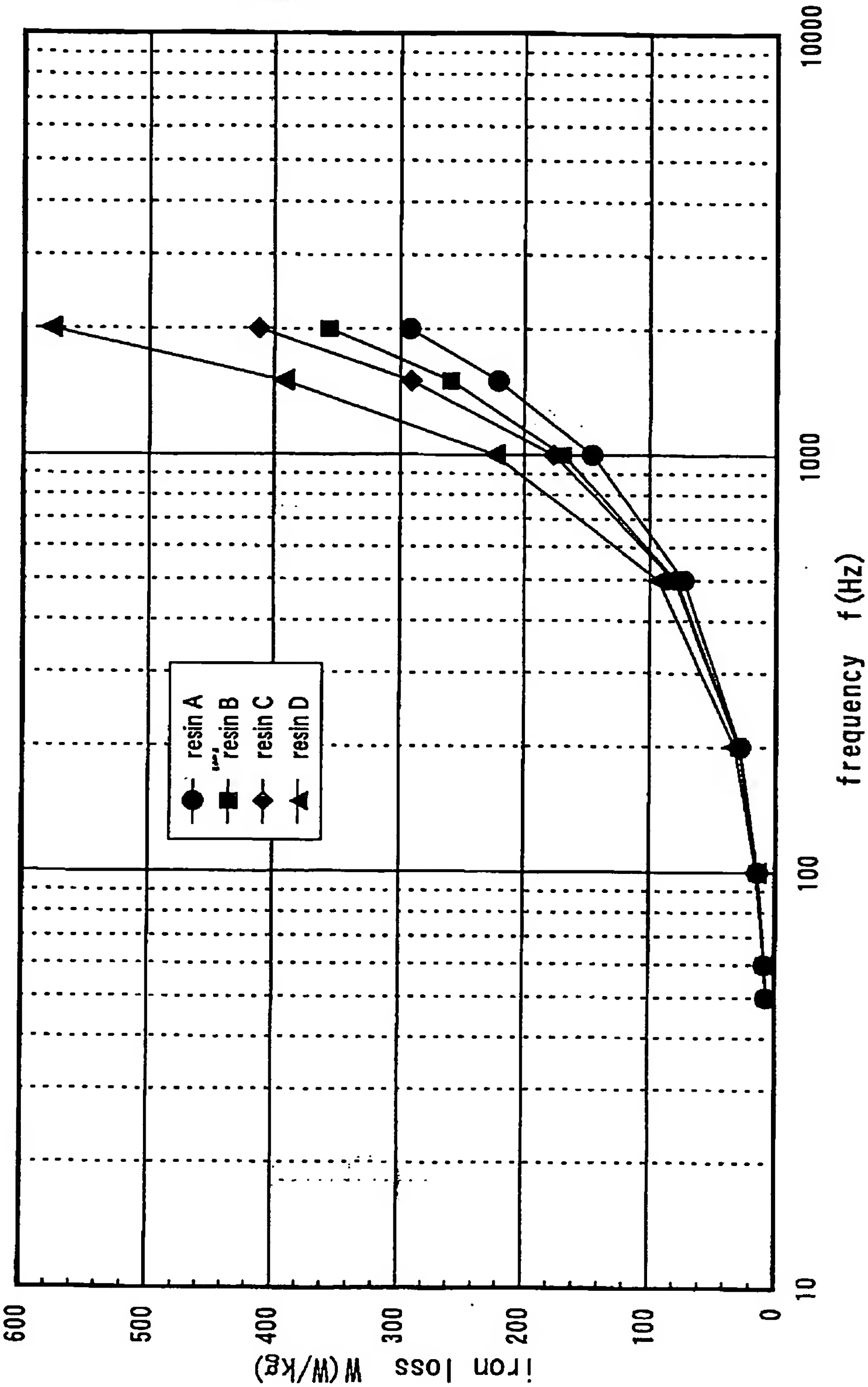

hysteresis loss Wh (W/kg)
600
500
400
300
200
100
0
frequency f (Hz)
10
100
1000
10000
resin A
resin B
resin C
resin D

Fig. 4



resin A
resin B
resin C
resin D
frequency f (Hz)
10
100
1000
10000
iron loss W(W/kg)
0
100
200
300
400
500
600

Fig. 5A

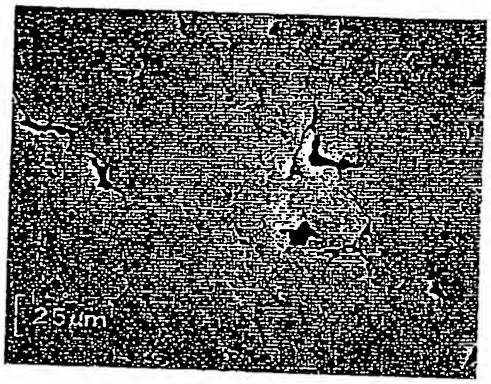


Fig. 5B

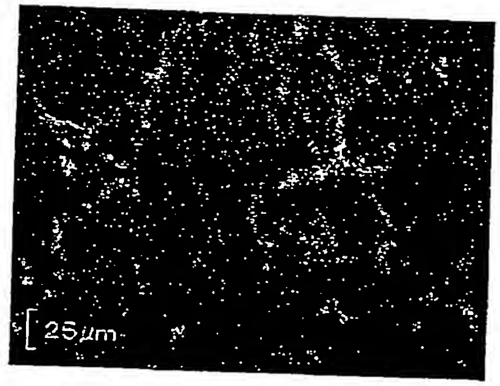


Fig. 5C

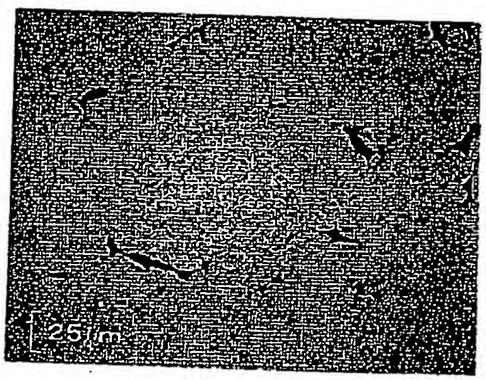


Fig. 5D